IS 4400-7 (1971): Methods of measurements on semiconductor devices, Part 7: Reverse blocking triode thyristors [LITD 5: Semiconductor and Other Electronic Components and Devices]

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(Reaffirmed 2006)

Indian Standard

METHODS OF MEASUREMENTS ON SEMICONDUCTOR DEVICES

PART VII REVERSE BLOCKING TRIODE THYRISTORS

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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METHODS OF MEASUREMENTS ON SEMICONDUCTOR DEVICES

PART VII REVERSE BLOCKING TRIODE THYRISTORS

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PART VII REVERSE BLOCKING TRIODE THYRISTORS

0. FOREWORD

0.1 This Indian Standard (Part VII) was adopted by the Indian Standards Institution on 15 November 1971, after the draft finalized by the Semiconductor Devices and Integrated Circuits Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard (Part VII) lays down methods of measurements on reverse blocking triode thyristors (abbreviated as thyristors) for characteristics covered in IS : 3700 (Part VII)-1970*.

0.3 Certain ratings are related to the extended performance of a given device under certain operating conditions and generally declared or assigned by the manufacturer based on his experience. Individual measurements for such ratings are often not feasible and hence methods of measurements for such ratings are not covered in this standard. It is usual for the supplier or user to evaluate these requirements in relation to the reliability and life requirements.

0.3.1 Such ratings as applicable to reverse blocking triode thyristors for which methods of measurements are not described, are:

a) voltage ratings [*see* **6.3** of IS : 3700 (Part VII)-1970*]
b) current ratings [*see* **6.4** and **6.5** of IS : 3700 (Part VII)-1970*]
c) frequency ratings [*see* **6.7** of IS : 3700 (Part VII)-1970*]
d) power dissipation ratings [*see* **6.8** of 3700 (Part VII)-1970*]
e) temperature ratings [*see* **6.9** of IS : 3700 (Part VII)-1970*]

0.4 The polarities of the sources shown in the circuits in this standard are applicable to P-gate thyristors. However, the circuits can be adapted for N-gate thyristors by changing the polarities of the metres and the sources, and also of the anode and cathode terminals.

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*Essential ratings and characteristics of semiconductor devices: Part VII Reverse blocking triode thyristors.

0.5 While preparing this standard, assistance has been derived from IEC Pub 147-2C (1970) Third supplement to Pub 147-2 (1963) 'Essential ratings and characteristics of semiconductor devices and general principles of measuring methods: Part 2 General principles of measuring methods' issued by International Electrotechnical Commission.

0.6 This standard is one of a series of Indian Standards on semiconductor devices. A list of standards so far prepared in this series is given on page 26.

0.7 In reporting the results of measurements made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

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1. SCOPE

1.1 This standard (Part VII) covers the methods of measurements on reverse blocking triode thyristors (abbreviated as 'thyristor') for characteristics covered in IS : 3700 (Part VII)-1970†.

2. TERMINOLOGY, GRAPHICAL SYMBOLS AND LETTER SYMBOLS

2.1 Terminology — For the purpose of this standard the terms and definitions given in IS : 1885 (Part VII/Sec 4)-1969‡ shall apply.

2.2 Graphical Symbols — For the purpose of this standard, the graphical symbols given in IS : 2032 (Part VIII)-1965§ shall apply.

2.3 Letter Symbols — For the purpose of this standard, the letter symbols given in IS : 3715 (Part I)-1971‖ and IS : 3715 (Part IV)-1971¶ shall apply.

3. THERMAL CONDITIONS

3.1 The measurements shall be made at the required thermal conditions specified in the relevant clauses of IS : 3700 (Part VII)-1970†. Measurements shall be carried out only after thermal equilibrium is reached.

4. GENERAL

4.1 The relevant conditions specified in IS : 4400 (Part I)-1967** shall apply in addition to those specfied in **4.1.1** and **4.1.2**.

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*Rules for rounding off numerical values (*revised*).

†Essential ratings and characteristics of semiconductor devices: Part VII Reverse blocking triode thyristors.

‡Electrotechnical vocabulary: Part VII Semiconductor devices, Section 4 Thyristors.

§Graphical symbols used in electrotechnology: Part VIII Semiconductor devices.

‖Letter symbols for semiconductor devices: Part I General aspects.

¶Letter symbols for semiconductor devices: Part IV Thyristors.

**Methods of measurements on semiconductor devices: Part I General.

4.1.1 *Precautions for dc Measurements*

4.1.1.1 For the measurements of the forward characteristics of thyristors, the quality of the source of direct current is not considered to be important, provided that the peak-to-peak ripple is less than 10 percent.

4.1.1.2 For the measurements of reverse characteristics, the peak-to-peak ripple of the voltage source should not exceed 1·0 percent and particular care should be taken to ensure that the voltage ratings of the thyristors are not exceeded due to any voltage transients.

4.1.2 *Precautions for ac Measurements*

4.1.2.1 Diodes may be included in source circuits in order to protect the amplifiers in the oscilloscope from unwanted half-cycle pulses.

4.1.2.2 Where low reverse and off-state currents are being measured it may be necessary to take suitable precautions, such as the use of a screened transformer and suitable earthing to avoid pick-up. Care should also be taken to avoid stray capacitances.

4.1.2.3 In addition, particular care should be taken to keep residual inductance as low as possible, especially for high current devices.

4.1.3 *Temperature Conditions*

4.1.3.1 For all measurements of electrical characteristics described, the conditions of temperature should be specified.

4.1.3.2 The measurements should be performed only after thermal equilibrium is reached.

4.2 Ratings

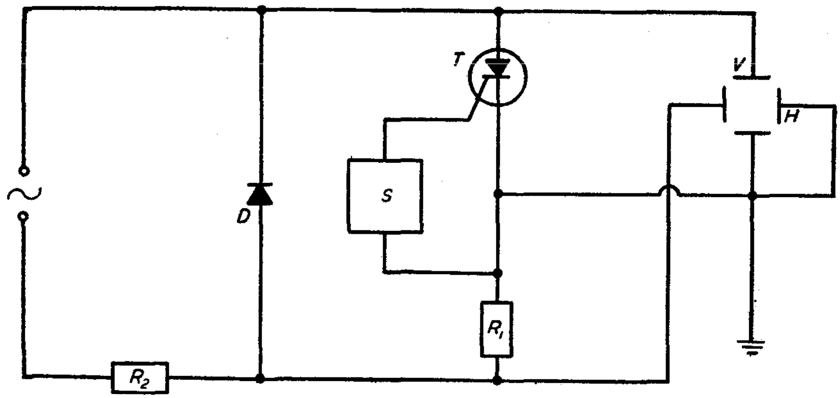
4.2.1 Attention is called to the desirability of keeping the test conditions such as applied voltages and currents within the maximum ratings. If the ratings are exceeded, the characteristics of the thyristor may be permanently altered and subsequent tests vitiated.

4.2.2 Care shall be exercised to guard against the presence of transients which might be of sufficient magnitude to cause the deleterious effects specified in **4.2.1**.

5. ELECTRICAL CHARACTERISTICS

5.1 Forward Characteristics — Figure 1 gives a circuit for the measurement of instantaneous on-state-voltage for specified conditions of bias and impedance of the gate circuit, using a half-sine wave voltage supply. The current is applied through the thyristor in the forward direction while the thyristor is in the on-state and the voltage-current curve is displayed on an oscilloscope (*see* Fig. 2).

The resistor R_2 included in the circuit (*see* Fig. 1) is introduced to limit the forward current of the diode D and hence should be low compared to forward resistance of the later.



T = Thyristor under test
R_2 = Protective resistor
S = Gate biasing source

FIG. 1 CIRCUIT FOR THE MEASUREMENT OF FORWARD CHARACTERISTICS

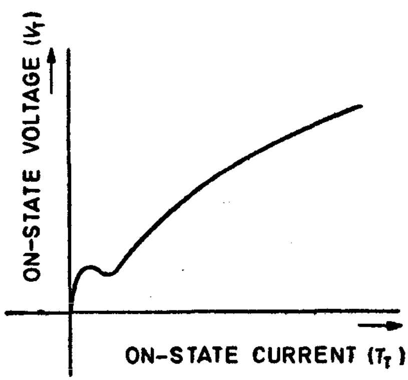
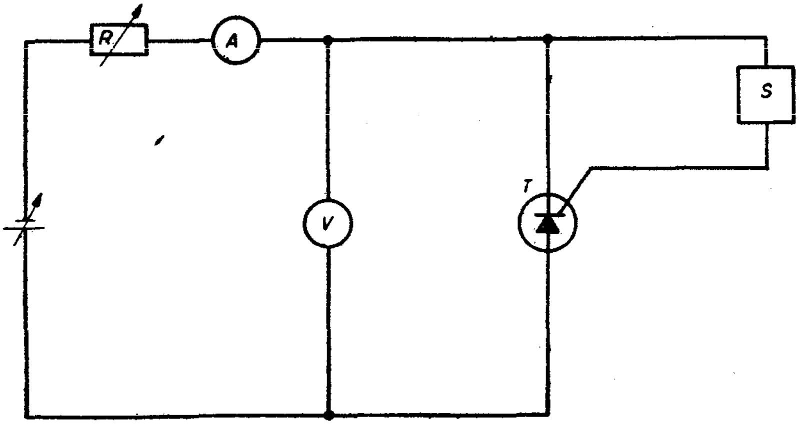


FIG. 2 GRAPHICAL REPRESENTATION OF ON-STATE VOLTAGE VERSUS ON-STATE CURRENT CHARACTERISTICS

5.2 On-State Voltage — On-state voltage shall be measured in the circuit given in Fig. 3. The specified on-state current is set after the thyristor switches to the on-state and the voltage between the anode and cathode terminals is measured under specified conditions of bias and impedance of the gate circuit.



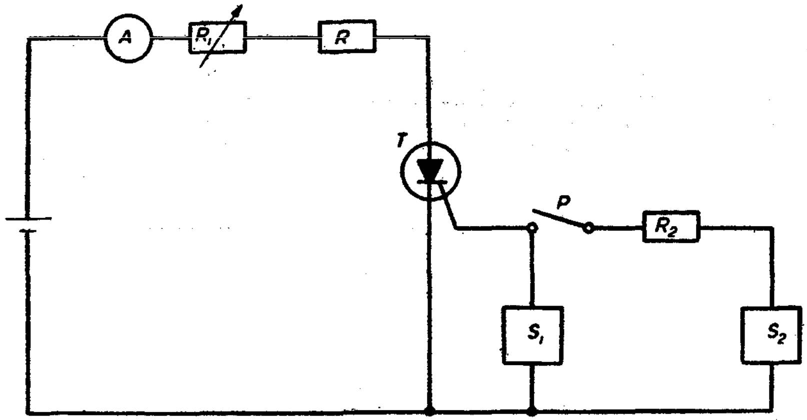
T = Thyristor under test
S = Gate biasing source

FIG. 3 CIRCUIT FOR THE MEASUREMENT OF ON-STATE VOLTAGE

5.3 Latching Current — The latching current shall be measured in the circuit given in Fig. 4. The anode and gate supplies are connected and the gate triggering conditions shall be set as specified. The resistance R_1 shall be set initially at its maximum resistance value so that the thyristor does not conduct continuously when switch *P* is closed and shall then gradually be reduced while the switch *P* is periodically depressed and released. Each time the switch is depressed, the ammeter reading will rise and then drop back to zero when the switch is released as long as anode current flowing through the thyristor is less than its latching current. When latching finally occurs, the ammeter will deflect and remain deflected as the switch is released. The value of the current as indicated at this transition point is the latching current.

5.4 Holding Current — The holding current shall be measured using the same set-up as for latching current given in Fig. 4. The anode and gate supplies are connected as shown in the figure. The anode supply voltage is fixed and the resistor (R_1) in the anode circuit is adjusted so that the on-state current which will flow when the thyristor is turned-on is high enough to ensure complete switching of the thyristor. The push-button switch is then closed and the gate current increased until the thyristor switches on and then the push-button is released. The resistor (R_1) in the anode circuit is then increased gradually, thus decreasing the on-state current until the thyristor turns off. The value of the on-state current immediately prior to the thyristor turning off is the holding current.

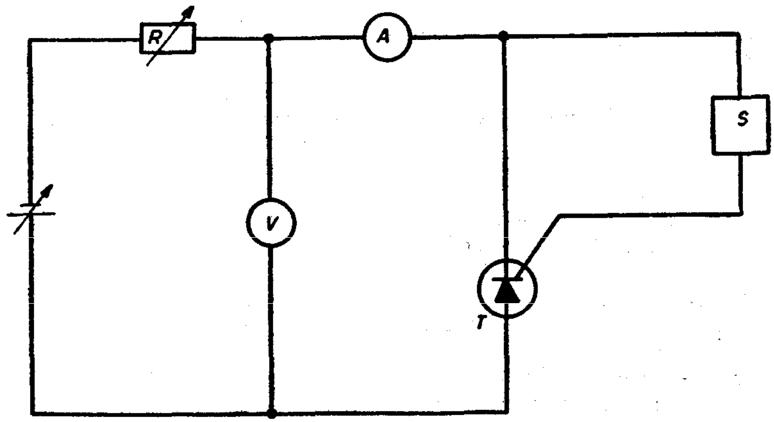
NOTE — Accidental open circuiting of resistance R_1 during measurement should not be mistaken for tunning-off of the thyristor and for determining the value of holding current.



T = Thyristor under test
P = Switch (push button type)
R_1 and R_2 = Protective resistors
S_1 = Gate biasing source
S_2 = Gate trigger source

FIG. 4 CIRCUIT FOR THE MEASUREMENT OF LATCHING CURRENT AND HOLDING CURRENT

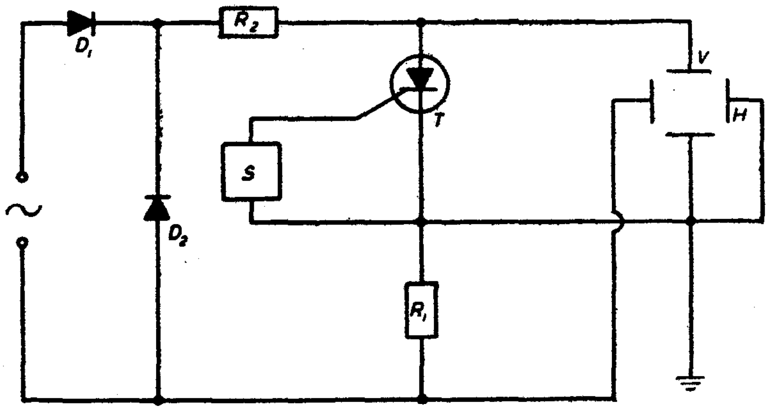
5.5 Off-State Current — The off-state current shall be measured in the circuit given in Fig. 5. The specified peak off-state voltage is applied through the protective resistor and the off-state current is measured under specified conditions of gate bias and impedance of the gate circuit. The protective resistor shall be sufficiently large to protect the ammeter and the device being measured, should the latter switch to the conducting state. It is also to be noted that considerable care shall be taken in shielding the equipment.



T = Thyristor under test S = Gate biasing source

FIG. 5 CIRCUIT FOR THE MEASUREMENT OF OFF-STATE CURRENT

5.6 Instantaneous Off-State Current — Figure 6 gives a circuit for the measurement of instantaneous values of off-state current as a function of off-state voltage for specified conditions of bias and impedance of gate circuit. The curve of voltage-current is displayed on the oscillascope. It is to be noted that considerable care shall be taken in shielding the equipment.



T = Thyristor under test
R_2 = Protective resistor
G = Gate biasing source

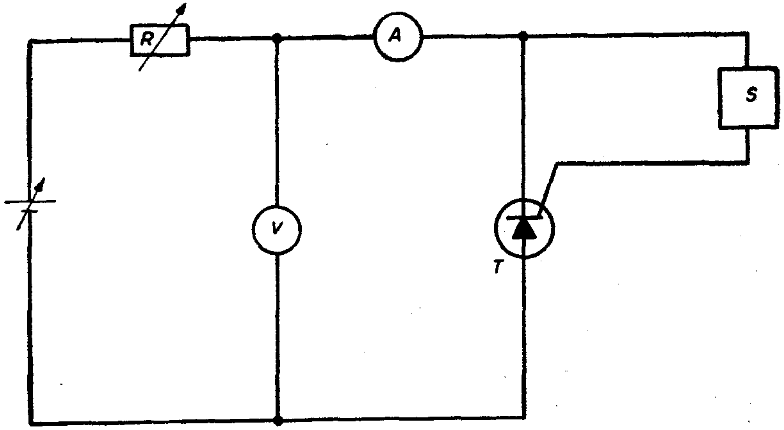
NOTE 1 — The use of the diodes D_1 and D_2 in this circuit is optional.

NOTE 2 — The peak reverse voltage of the diode D_2 should be commensurate with the thyristor rating.

FIG. 6 CIRCUIT FOR THE MEASUREMENT OF INSTANTANEOUS OFF-STATE CURRENT

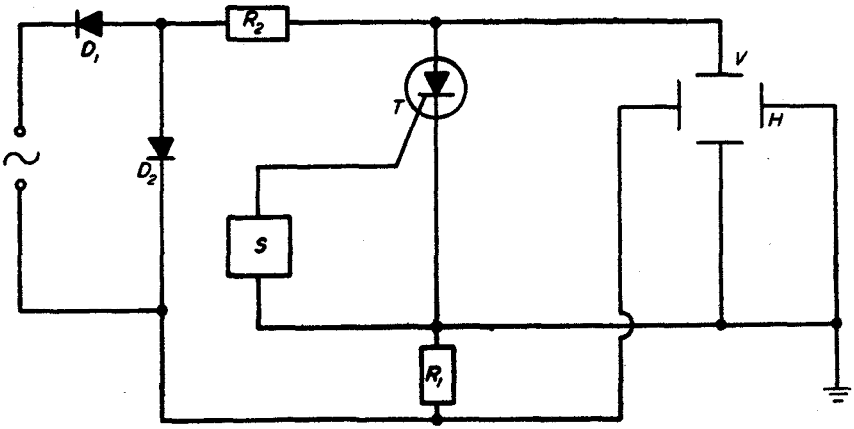
5.7 Reverse Current — Figure 7 gives a circuit for the measurement of reverse current. The specified value of reverse voltage is applied through the protective resistor R and the reverse current is measured under specified conditions of gate bias and impedance of the gate circuit. Considerable care should be taken in shielding the equipment.

5.8 Instantaneous Reverse Current — Figure 8 gives a circuit for the measurement of instantaneous values of reverse current as a function of reverse voltage. The curve of voltage-current is displayed on the oscilloscope. Considerable care shall be taken in shielding the equipment.



T = Thyristor under test
S = Gate biasing source

FIG. 7 CIRCUIT FOR THE MEASUREMENT OF REVERSE CURRENT



T = Thyristor under test
R_2 = Protective resistor
S = Gate biasing source

NOTE 1 — The use of diodes D_1 and D_2 in this circuit is optional.

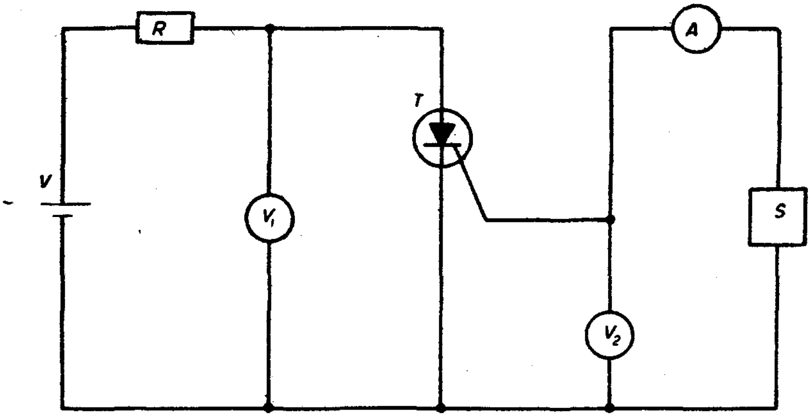
NOTE 2 — The peak reverse voltage of the diode D_2 should be commensurate with the thyristor rating.

FIG. 8 CIRCUIT FOR THE MEASUREMENT OF INSTANTANEOUS REVERSE CURRENT

5.9 Gate Trigger Current and Gate Trigger Voltage — Gate trigger voltage and current can be measured in the circuit given in Fig. 9. The specified continuous voltage *V* [*see* Note under **7.8** of IS : 3700 (Part VII)-1970*] is applied in the forward direction. Then the voltage between gate and cathode terminals is increased gradually from zero until the thyristor is switched to the on-state and the voltage between anode and cathode terminals decreases suddenly. The voltage between gate and cathode terminals and the gate current required to trigger the thyristor are the gate trigger voltage and current respectively.

NOTE — Care should be taken to avoid error introduced by the connection of voltmeter and ammeter in the gate circuit. The voltmeter V_2 should be removed when measuring gate trigger current.

The gate signal should be applied at a sufficiently slow rate to avoid errors due to damping in the meter movements and to permit accurate observation of the meter readings as the thyristor switching point is approached.



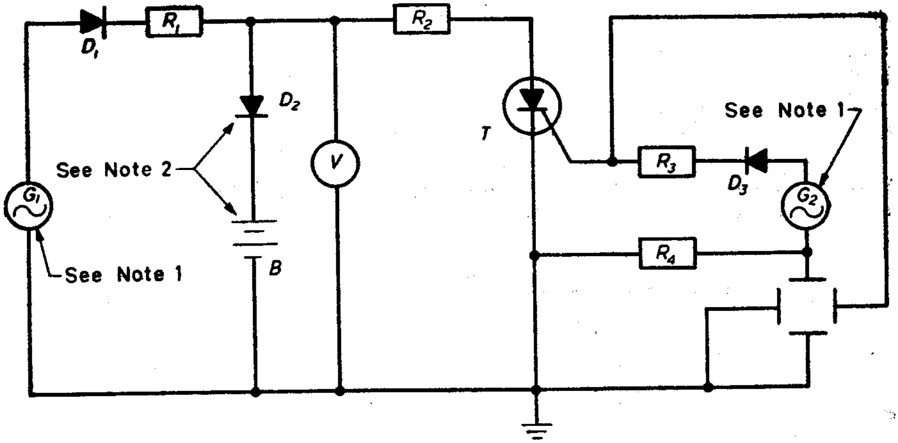
T = Thyristor under test
S = Gate biasing source
R = Current limiting resistor

FIG. 9 CIRCUIT FOR THE MEASUREMENT OF GATE TRIGGER CURRENT AND GATE TRIGGER VOLTAGE

5.9.1 When the circuit is used to determine the values of gate trigger current and gate trigger voltage that will trigger every thyristor, the anode supply voltage should be low, preferably 12 V or less.

*Essential ratings and characteristics of semiconductor devices: Part VII Reverse blocking triode thyristors.

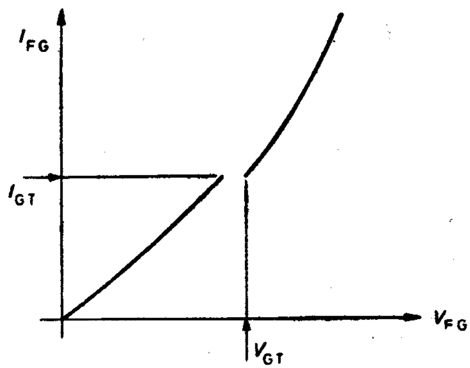
5.10 Gate Non-trigger Current and Gate Non-trigger Voltage — The gate non-trigger current and the gate non-trigger voltage shall be measured in the circuit given in Fig. 10. The anode supply shall be intermittent and synchronized with the gate voltage and shall be adjusted to the value of the specified peak off-state voltage. A synchronized half-sine-wave voltage, sufficiently large to make the thyristor switch, is applied to the gate circuit. The point of discontinuity on the trace in the gate current voltage



NOTE 1 — The two supply sources G_1 and G_2 should be at mains frequency of 50 Hz.

NOTE 2 — The battery B and the clamping diode D_2 provide the intermittent on-state voltage.

FIG. 10 CIRCUIT FOR THE MEASUREMENT OF GATE NON-TRIGGER CURRENT AND GATE NON-TRIGGER VOLTAGE



I_{GT} = Gate Trigger Current
V_{GT} = Gate Trigger Voltage

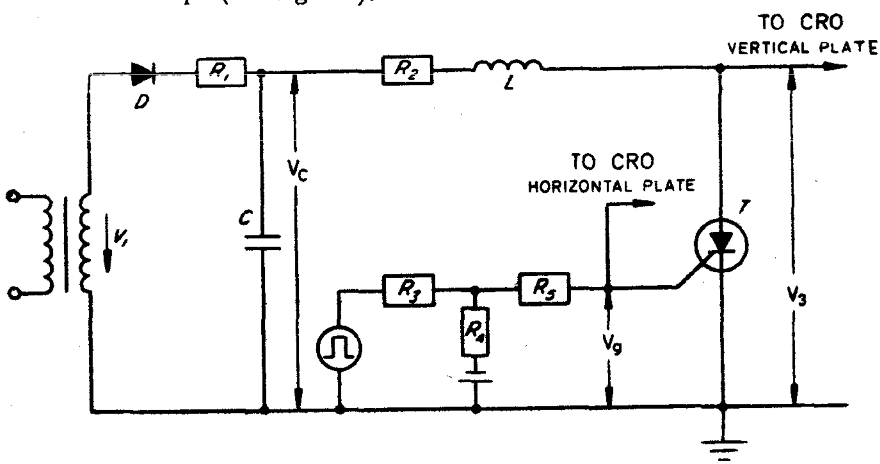
FIG. 11 GATE CURRENT VERSUS GATE VOLTAGE CHARACTERISTIC

characteristic as a result of thyristor switching, displayed on the oscilloscope is observed. This is shown in Fig. 11. The current and voltage, immediately prior to that point, are the gate non-trigger current and voltage respectively.

5.10.1 When the circuit is used to determine the values of gate trigger current and gate trigger voltage that will trigger every thyristor, the anode supply voltage should be low, preferably 12 V or less.

5.11 Gate Controlled Turn-On Time

5.11.1 The measurement circuit is shown in Fig. 12. The capacitor C is charged to the specified voltage V_C through diode D during the positive half cycles of 50 Hz supply voltage. During the negative half cycles, the thyristor to be measured is turned-on by means of a synchronized trigger signal, and capacitor C is discharged (*see* Fig. 13). The waveforms of gate voltage V_g and anode voltage V_a of the thyristor are displayed on a dual-trace oscilloscope (*see* Fig. 14).



T = Thyristor under test

FIG. 12 CIRCUIT FOR THE MEASUREMENT OF GATE CONTROLLED TURN-ON TIME

5.11.2 Resistor R_1 is used to limit the charging current and protect the diode D. Resistor R_2 is used to limit the peak current of the thyristor to its specified value. The time constant of $R_2\,C$ should be not less than ten times the specified rise time, but shall be small enough to allow complete discharge of capacitor C prior to the next charging cycle. The inductor L is used for protection of the thyristor and includes any stray inductance due to circuit wiring. The ratio L/R_2 should be specified. The gate circuit conditions and gate bias should be specified. The network connected to the gate circuit is an example for illustration.

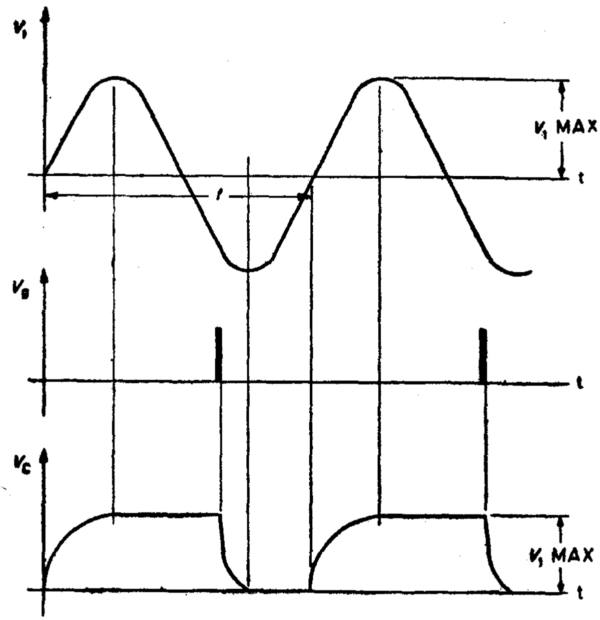


FIG. 13 INPUT WAVEFORMS

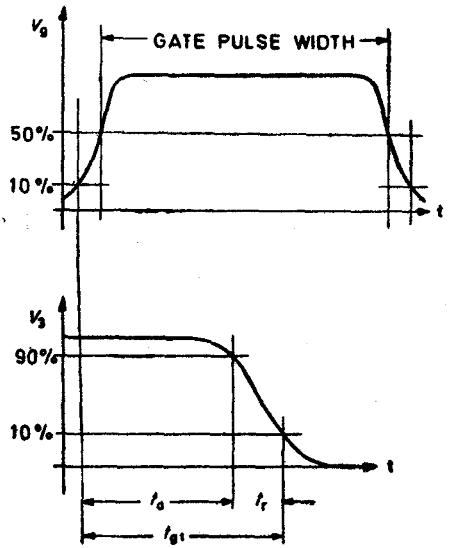


FIG. 14 GATE CONTROLLER TURN-ON TIME

5.11.3 The rise time of the trigger signal should not exceed 10 percent of the specified delay time. The duration of the trigger signal should be sufficiently long relative to the specified turn-on time that the result is not affected within the desired accuracy of measurement.

5.11.4 The gate controlled turn-on time is the sum of the delay time t_d and the rise time t_r of the thyristor anode current. The delay time is measured as the time interval between the 10 percent point on the leading edge of the gate trigger pulse and the time when the thyristor voltage has decreased to 90 percent of its initial value (before triggering). The rise time is measured as the time interval during which the thyristor anode voltage has fallen from 90 percent to 10 percent of its initial value (before triggering).

When the off-state voltage of the thyristor is not high compared with its on-state voltage, the measurement of rise time should be measured as the time interval between 90 percent and 10 percent of the difference between the off-state and on-state voltages.

5.12 Circuit Commutated Turn-Off Time

5.12.1 Circuit commutated turn-off time is the sum of the reverse recovery time t_{rr} and the gate recovery time t_{gr} (*see* Fig. 15). It is measured from the instant when the principal current has fallen to zero and the time when the thyristor is capable of blocking the off-state voltage without switching to the on-state.

5.12.2 The circuit commutated turn-off time is dependent upon:

a) the magnitude of the on-state current;

b) the rate of fall of on-state current $\frac{di}{dt}$;

c) The operating temperature;

d) The magnitude of the reverse voltage applied during the turn-off interval;

e) The magnitude and rate of rise of the off-state voltage applied at the end of the turn-off interval; and

f) The gate bias conditions during the turn-off interval and the re-application of the off-state voltage.

5.12.3 The basic circuit diagram in Fig. 16 indicates the operating principles of a circuit used to generate the waveforms shown in Fig. 15. For convenience, the circuit uses current generators and ideal switches.

5.12.4 The operation of the circuit is as follows:

a) Switches S_2 and S_4 are closed simultaneously causing the thyristor to switch to the on-state and conduct the specified current I_T. Switch S_4 is then opened and the trigger circuit disconnected from the thyristor, the on-state current being unaffected.

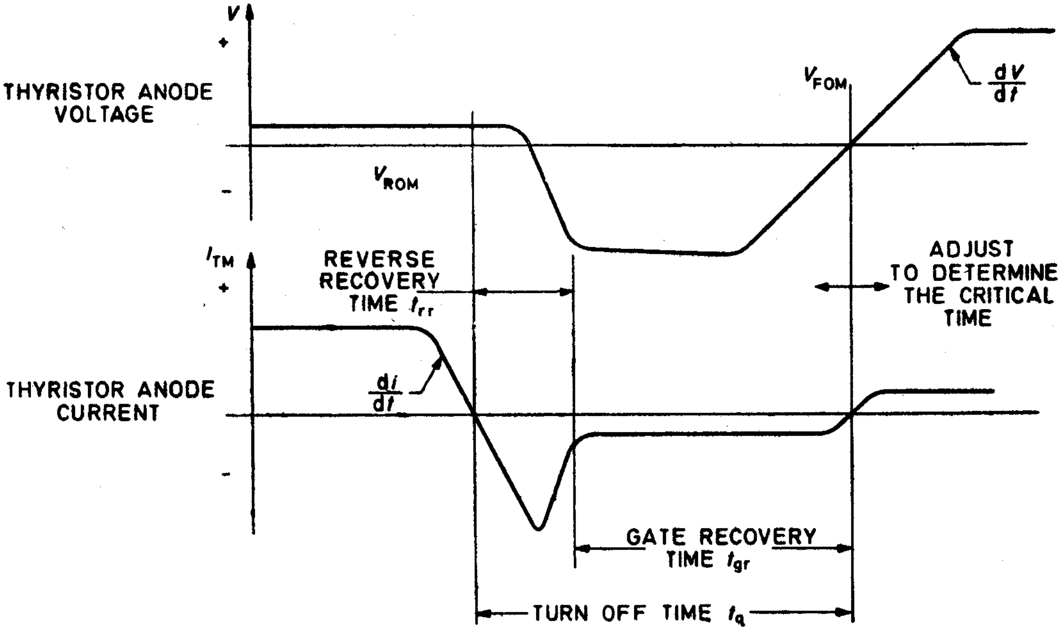
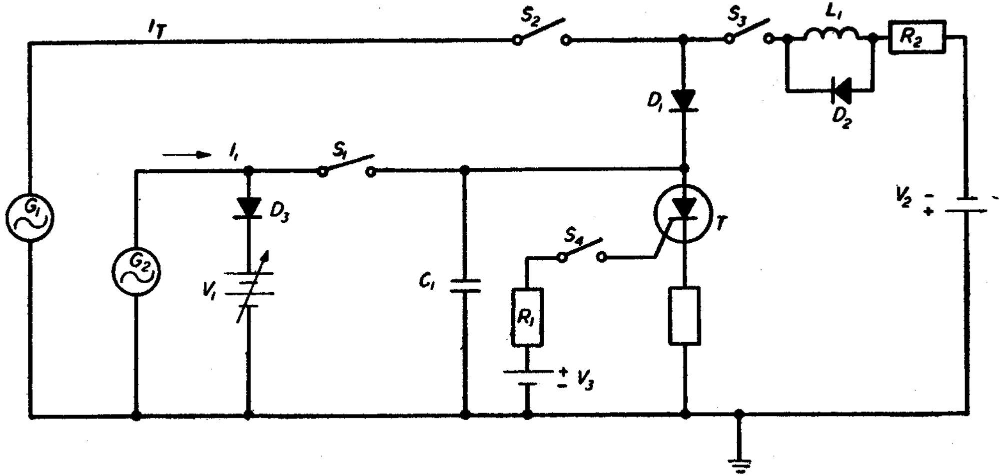


FIG. 15 THYRISTOR SWITCHING WAVEFORMS



T = Thyristor under test

G_1 and G_2 = Constant current generator

NOTE — Switches S_1 to S_4 are electronic switches

FIG. 16 BASIC CIRCUIT FOR THE MEASUREMENT OF CIRCUIT-COMMUTATED TURN-OFF TIME

b) After the specified conduction time, switch S_3 is closed and a reverse voltage of specified amplitude and rate of change is applied across the thyristor to cause current reversal through the thyristor.

Switch S_1 is closed so that forward off-state voltage of specified amplitude and rate of change is applied across the thyristor to determine when the thyristor is capable of blocking the off-state voltage without switching to the on-state.

The switching sequence (S_3 to S_1) is repeated using successively shorter time intervals until the time interval is just long enough to allow the off-state voltage to be applied without breakover.

5.12.5 In the circuit, diode D_1 shall have a reverse recovery time longer than the reverse recovery time of the thyristor, so that the full reverse voltage cycle appears across the thyristor. Diode D_2 is used to prevent a commutation voltage transient when the thyristor begins to recover its reverse blocking capability. Diode D_3 is used in conjunction with the voltage V_1 to limit the forward off-state voltage. Inductor L_1 and resistor R_2 are used to determine the rate of current change during switching from the on-state. The current I_1 completes the reverse recovery of diode D_1 and then charges capacitor C_1 linearly with time at a rate equal to I_1/C_1 producing the required rate of rise of forward off-state voltage at the end of the switching cycle.

5.12.6 The measurement is usually made in a circuit operating on a repetitive basis at supply frequency so that a continuous oscilloscope display is possible. Figure 17 shows an example of such a circuit. The gate trigger generator is synchronized with the supply frequency and provides trigger pulses on the half cycles following the charging of capacitors C_5 and C_2. Trigger pulses are applied to the thyristor under test T_a and to thyristors T_b and T_c, in that order, to perform the switching functions of switches S_4, S_3 and S_1 of Fig. 16.

5.12.7 The on-state current I_T is obtained from the charge in capacitor C_5 which is charged by means of an adjustable halfwave rectified supply. The time constant of C_5 and R_1 shall be sufficiently large so that the specified on-state current is essentially constant over the specified conduction period. The conduction period is ended by the gate pulse which triggers thyristor T_b allowing the reverse voltage of capacitor C_2 to be applied through the resistor R_2, inductor L_1 and diode D_1 across the thyristor under test, the functions and requirements of R_2, L_1 and D_1 being as described for the basic circuit.

5.12.8 The turn-off time interval is ended by the gate pulse which triggers thyristor T_c. The circuit used in Fig. 17 to generate the forward off-state voltage differs from that shown in the basic circuit in Fig. 16. When thyristor T_c is triggered, diode D_3 is reverse biased (because of the voltage on capacitor C_4), causing the current through inductor L_2 to

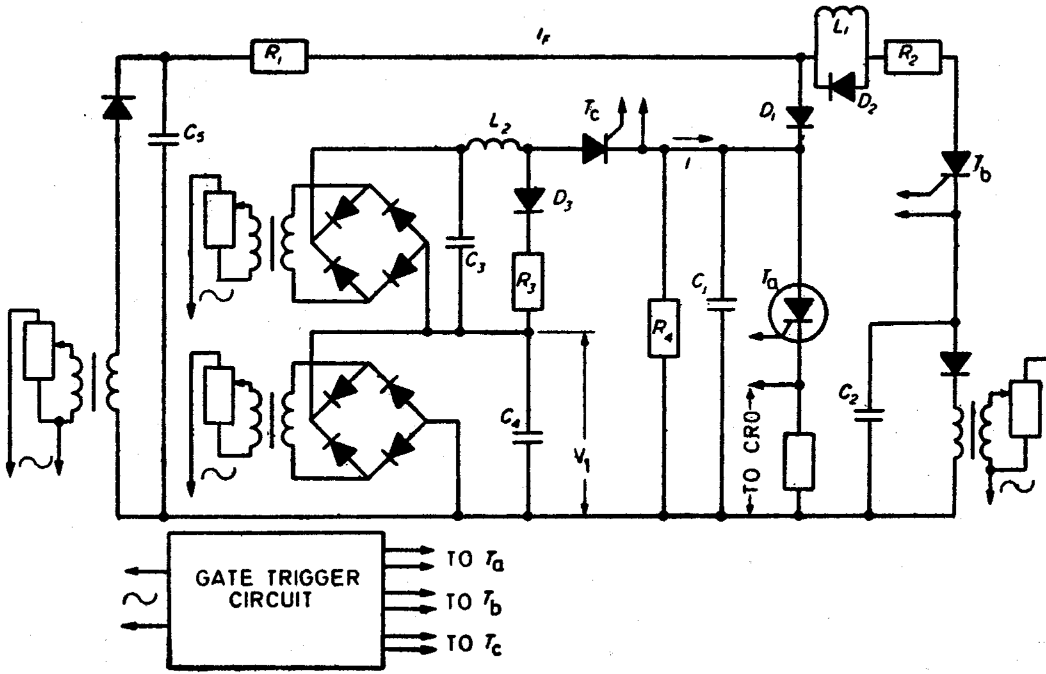


Fig. 17 Typical Circuit for the Measurement of Circuit Commutated Turn-Off Time

be diverted through T_C to charge capacitor C_1 at a linear rate. The inductance of L_2 shall be large enough to maintain constant current until capacitor C_1 charges to a voltage equal to the sum of voltages V_3 and V_4. At this point, diode D_3 starts to conduct and clamps the off-state voltage applied to the thyristor under test. Resistor R_4 is used to discharge capacitor C_1 during the conduction period before the next switching cycle. Resistor R_3 serves to control the value of the constant current through L_2 and D_3.

5.12.9 In addition, the following considerations are applicable:

a) The time constant R_1C_5 shall be large enough to maintain essentially constant current during the conduction period. For test currents above 100 amperes, a properly designed lumped constant transmission line and a reduced repetition rate may result in a more practical source of conduction current.

b) Thyristor T_b does not turn-off until the charges on C_2 and C_5 reach equilibrium. This results in considerable power loss in R_1 and R_2. This loss can be considerably reduced by adding additional circuitry for turning off thyristor T_b following the triggering of thyristor T_c or by reducing the pulse repetition rate.

c) Resistor R_4 provides a discharge path for capacitor C_1. The current drawn by R_4 shall be less than the holding current of thyristor T_c so that it may turn-off after C_1 becomes charged.

d) Effects of distributed capacitance in L_2 reverse recovery of diodes D_1 and D_3 and wiring inductance may cause undesirable oscillations in the re-applied forward voltage waveform. These effects can be minimized by good design practices including the use of suitable damping resistances (not included) in Fig. 17.

e) Good design practice should be used to avoid exceeding ratings of the components selected.

5.13 Total Power Loss — The total power loss is composed primarily of the following losses:

a) Forward conduction losses (*see* **5.1**),
b) Forward blocking losses (*see* **5.5**),
c) Reverse blocking losses (*see* **5.7**), and
d) Gate power losses (*see* **5.10**).

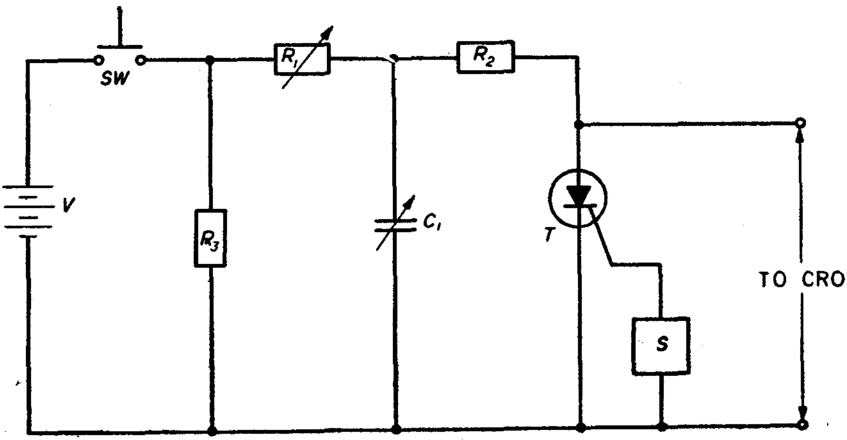
5.13.1 These losses are individually computed by the integration of current voltage curves obtained from the measurements made as indicated against each.

5.13.2 The total loss is averaged over a whole cycle and plotted against average forward current for various conduction angles.

NOTE — Switching losses also are to be taken into account for high frequency application above 400 Hz. (These depend on individual applications and switching conditions and hence no general method is prescribed.)

5.14 Critical Rate of Rise of Off-State Voltage—The measurement is made at a specified applied anode or principal voltage and the rate of rise is increased until the thyristor switches from the off-state to the on-state. The waveform of the applied voltage is exponential.

5.14.1 *Exponential Rise Method*— Figure 18 shows an example of a typical circuit and Fig. 19 shows a graphical representation of exponential waveform. This measurement is performed with an exponential waveform of specified amplitude with the device initially unenergized. The time constant τ is determined at the point of breakover.



S = Gate biasing source
T = Thyristor under test
S_W = Switch

FIG. 18 CIRCUIT FOR MEASUREMENT CRITICAL RATE OF RISE OF OFF-STATE VOLTAGE BY EXPONENTIAL RISE METHOD

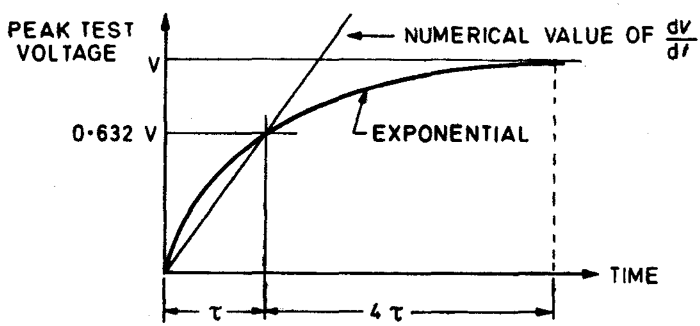


FIG. 19 EXPONENTIAL RISE WAVEFORM

5.14.2 The rate of rise is calculated as follows:

$$\text{Critical rate of rise} = \frac{\text{Peak test voltage} \times 0{\cdot}632}{\tau}$$

5.14.3 The critical rate of rise of off-state voltage is influenced by the value of off-state voltage. Therefore, the measurement should be done with a constant source voltage and variable time constant.

5.14.4 The measurement is performed by decreasing either the resistance R_1 or the capacitor C_1 until the device under test switches to the on-state, or the specified dv/dt limit value is reached without switching. The source voltage V shall be maintained at the specified value.

5.14.5 *Circuit Requirements*

a) Resistor R_2 is a current limiting resistor. The values of R_2 and C_1 shall be selected to minimize waveform distortion due to thyristor and circuit wiring impedances.

b) Resistor R_1 and capacitor C_1 form a network to give the required exponential rate of rise of voltage.

c) Resistor R_3 is used to discharge the capacitor C_1, while switch S_W is open, so that the test may be performed on a repetitive basis.

d) Switch S_W is used to energize the circuit and should have a closure time including bounce of not more than 10 percent of the practical time constant. The switch should be closed for a minimum period of 10 times the time constant.

e) The repetition rate should be low enough so that doubling its value does not change the result within the designed accuracy of measurement.

6. THERMAL CHARACTERISTICS

6.1 Reference Point Temperature

6.1.1 For devices where a hole has been drilled by the manufacturer for this purpose, the temperature of the case is measured by means of a thermocouple inserted into this hole. The thermocouple should be not larger than 0·25 mm. The thermocouple lead should be formed by welding rather than by soldering or twisting. The lead is inserted into the hole which is then closed over the thermocouple lead by tapping the metal at the edges of the hole.

6.1.2 For other devices, the temperature at the reference point is measured by means of a temperature-sensitive element having negligible thermal capacity which is cemented, soldered, clamped or held rigidly against the case of the device so as to ensure a negligible thermal resistance.

6.2 Thermal Resistance and Transient Thermal Impedance

6.2.1 *General* — The measurement of thermal resistance and transient thermal impedance is based on the use of a temperature-sensitive parameter as an indicator of virtual junction temperature. The on-state voltage of the thyristor at a small percentage of the rated on-state current is normally used as the temperature-sensitive parameter.

6.2.2 *Thermal Resistance* — Thermal resistance is calculated by measuring two powers P_1 and P_2, the reference point temperature being T_1 and T_2 respectively for the same indication of the chosen temperature sensitive parameter like on-state voltage at a small percentage of the rated on-state current (*see* **6.2.1**). Power P_1 is applied to the thyristor while maintaining a temperature T_1 at the reference point by suitable means (an oven for ambient, bath for case, etc). The flow of power P_1 is interrupted to permit measurement of the selected temperature-sensitive parameter immediately upon interruption of the power.

6.2.2.1 Power P_2 is then applied to the device and adjusted while simultaneously maintaining another temperature T_2 at the reference point so that the temperature-sensitive parameter measures the same value as in **6.2.2.**

6.2.2.2 The thermal resistance R_{th} is calculated from the formula:

$$R_{th} = \frac{T_2 - T_1}{P_1 - P_2}$$

6.2.3 *Transient Thermal Impedance*

6.2.3.1 A calibration curve is prepared for the device by measuring the on-state voltage at a selected value of measuring current, as a function of virtual junction temperature, by varying the device temperature externally, for example, by means of an oil bath. Discontinuities as shown in curve *B* of Fig. 20 indicate partial switching which should be corrected by selecting a higher value of measuring current.

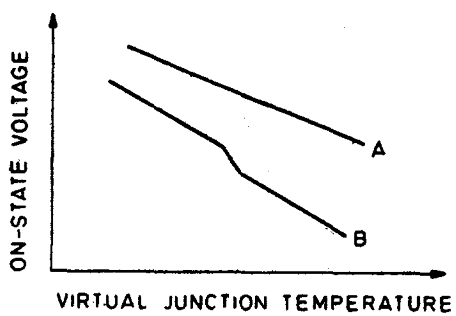
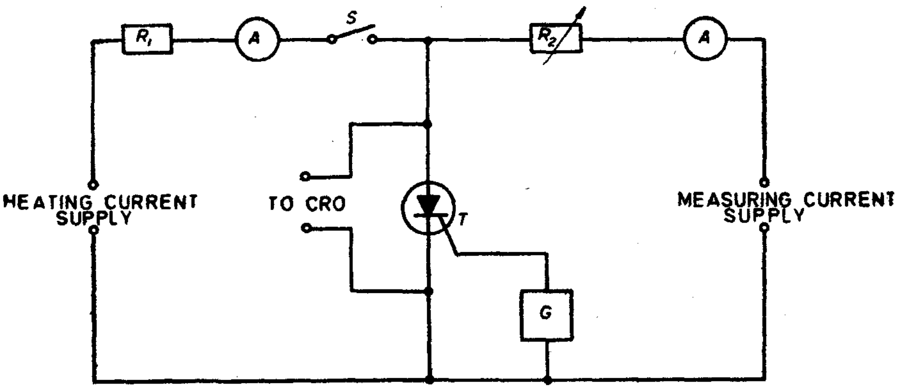


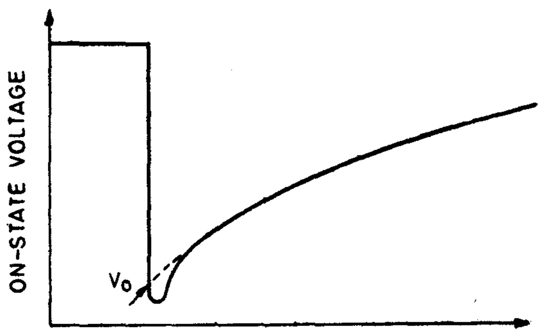
Fig. 20 Calibration Curve

6.2.3.2 A measuring circuit as shown in Fig. 21 may be used to obtain the data required for calculating the transient thermal impedance characteristic curve. After applying the heating current and waiting until thermal equilibrium is established, the power dissipated in the device is measured and recorded. The heating current supply is then interrupted, and the on-state voltage corresponding to the measuring current supply is recorded as a function of time as shown in Fig. 22. This may be accomplished by photographing the oscilloscope trace. The measurement may be repeated at different oscilloscope sweep rates in order to measure adequately the on-state voltage over the entire time range. The reference point temperature shall be monitored as a function of time. Since this change is relatively small and slow, a thermistor or thermocouple measuring system should be adequate.



G = Gate biasing source
T = Thyristor under test
S = Switch

FIG. 21 CIRCUIT FOR MEASURING TRANSIENT THERMAL IMPEDANCE



Time in log scale.

FIG. 22 ON-STATE VOLTAGE CURVE

6.2.3.3 The curve of on-state voltage as a function of time can be converted to virtual junction temperature versus time by means of the calibration curve.

6.2.3.4 Transient thermal impedance is calculated as follows:

$$Z_{th}\,(t) = \frac{(A - B) - (A' - B')}{P}$$

where

$Z_{th}\,(t)$ = transient thermal impedance at time 't',

A = virtual junction temperature at the time of heating current interruption,

B = reference point temperature at the time of heating current interruption,

A' = virtual junction temperature at time 't' seconds after heating current interruption,

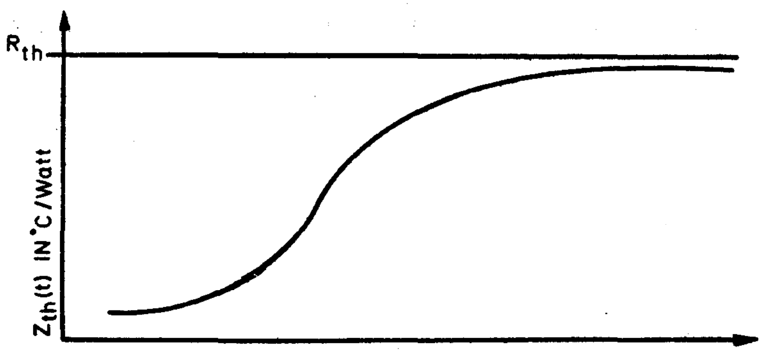
B' = reference point temperature at time 't' seconds after heating current interruption, and

P = power dissipated in the device.

6.2.3.5 Figure 23 illustrates the shape of a typical transient thermal impedance curve.

6.2.4 *Precautions*

6.2.4.1 The heating power applied should be either dc or of a sufficiently high frequency that the fluctuation of the virtual junction temperature is negligible. The measurement of on-state voltage should be



t = Time after heating current interruption (in log Scale)

FIG. 23 TRANSIENT THERMAL IMPEDANCE CURVE

made at a time following the power interruption(s) such that the non-thermal transients have decayed, but before the change of virtual junction temperature is significant.

It is for this reason that the electronic switching is used; the switch circuit and time delay of measurement after power interruption should also be specified.

6.2.4.2 Difficulties with this measurement method are due to ambiguity in determining the value of virtual junction temperature at the time of current interruption. Non-thermal voltage transients occur due to the excess charge carriers present after the heating current is interrupted. This difficulty can be avoided by extrapolating the on-state voltage versus time curve back to zero time from a time at the end of which the device is shown to be in charge equilibrium. This time can be estimated from life time observations or by performing the measurements at different power levels and noting the shortest time for which the virtual junction temperature is a linear function of power dissipation. The dotted portion of the on-state voltage curve in Fig. 22 illustrates the extrapolation of the point shown as V_0. Another source of non-thermal transients in the on-state voltage characteristics is due to the collapse of the magnetic field around the device when the heating current is interrupted.

7. MEASUREMENT OF CHARACTERISTIC CURVES

7.1 Mean On-State Current Versus Mean Power Dissipation for Various Conduction Angles — This curve shall be obtained as a computed curve directly from the power loss measurements (*see* **5.13**) for different conduction angles.

7.2 Mean On-State Current Versus Maximum Permissible Reference Point Temperature for Various Conduction Angles — This curve is a computed curve obtained from the power loss measurements (*see* **5.13**) for different conduction angles and from the thermal resistance measurements (*see* **6.2.2**).

7.3 Gate Triggering Characteristics — This curve shall be obtained from the gate trigger current and gate trigger voltage measurements (*see* **5.9**) and gate non-trigger current and gate non-trigger voltage measurements (*see* **5.10**).

7.4 On-state Voltage Versus On-State Current on Various Temperatures — This curve shall be obtained from the forward characteristic measurements made as specified in **5.1** at different temperatures.

7.5 Transient Thermal Impedance as a Function Time — *See* **6.2.3**.

7.6 Holding Current Versus Reference Point Temperature — This curve shall be obtained from the holding current measurements made in accordance with **5.4**.

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5000 Dimensions of semiconductor devices

NOTE — Standards on dimensions of semiconductor devices are published in loose leaf form (individually priced at Rs 3·00 per standard) and are supplied in an attractive binder (priced at Rs 8·00). So far 26 standards have been published.

5001-1969 Guide for preparation of drawings of semiconductor devices

5469-1969 Code of practice for the use of semiconductor junction devices

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